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Japan

NEW DIAMOND FORUM LECTURES

JPRS-JST-91-032
5 NOVEMBER 1991

SCIENCE & TECHNOLOGY
JAPAN

NEW DIAMOND FORUM LECTURES

916C3809 Tokyo NEW DIAMOND FORUM: ABSTRACTS OF LECTURES AT 6TH GENERAL SESSION SPECIAL LECTURES in Japanese Jun 91 pp 1-12, 1-31

CONTENTS

Future Prospect for Fine Ceramics

916C3809A Tokyo NEW DIAMOND FORUM: ABSTRACTS OF LECTURES AT 6TH GENERAL SESSION SPECIAL LECTURES in Japanese Jun 91 pp 1-12

[Article by Yoshihisa Ishiguro, Fine Ceramics Office chief, Consumer Goods Industries Bureau, Ministry of International Trade and Industry: "Future Prospect for Fine Ceramics"]

[Text] **Industrializing New Diamond**

4 June 1991
6th New Diamond Forum General Session

1. Presentation of Development Direction (Visicn Making)

Expected industrial scale, conception

2. Promotion of Research and Development

Grasping of actual state of research and development

Promotion of key projects

(Example: Project for "hazardous environment monitoring system for solving earth environmental problems")

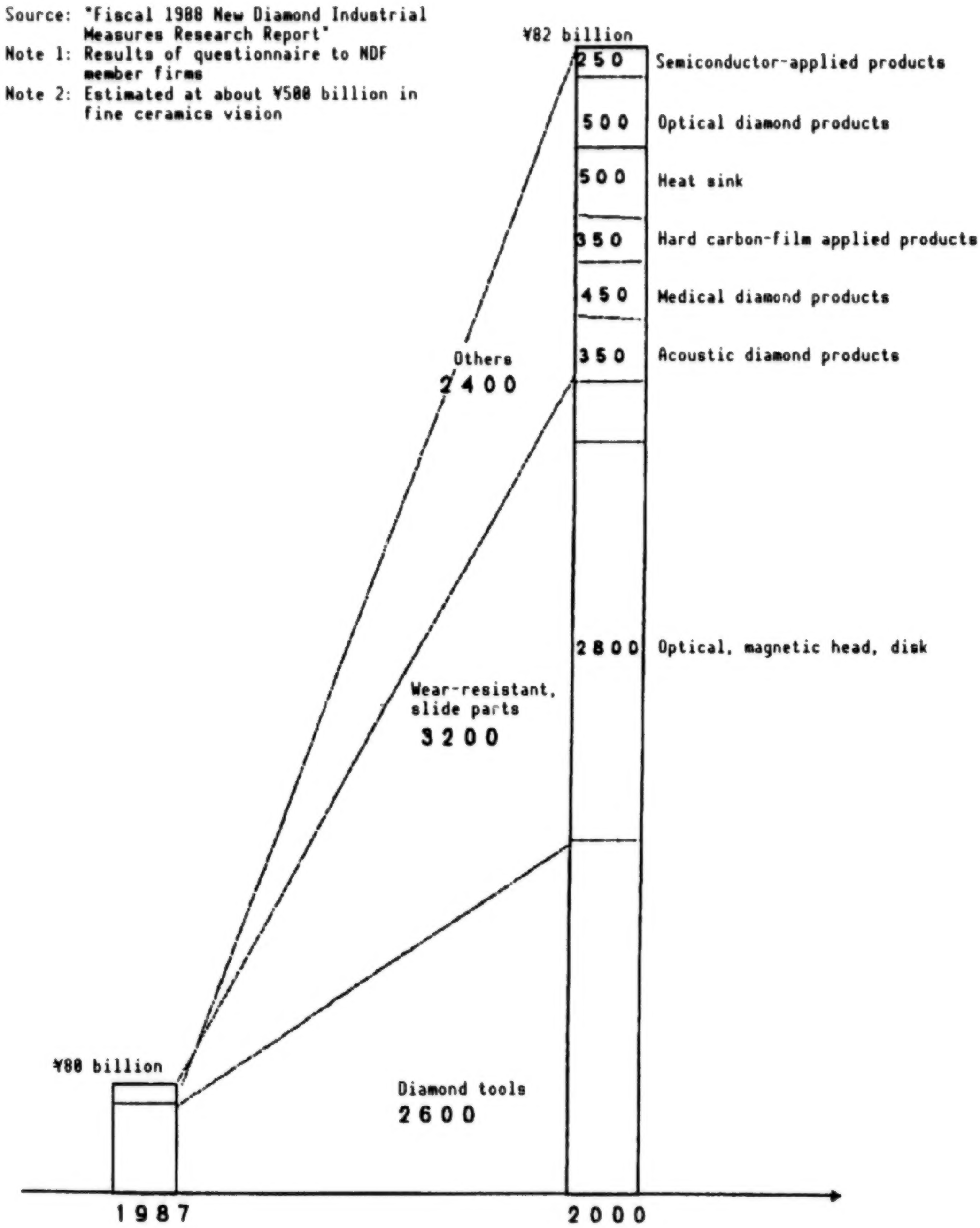
Promotion of related basic research

3. Completion of Industrial Foundation (Completion and promotion of NDF system)

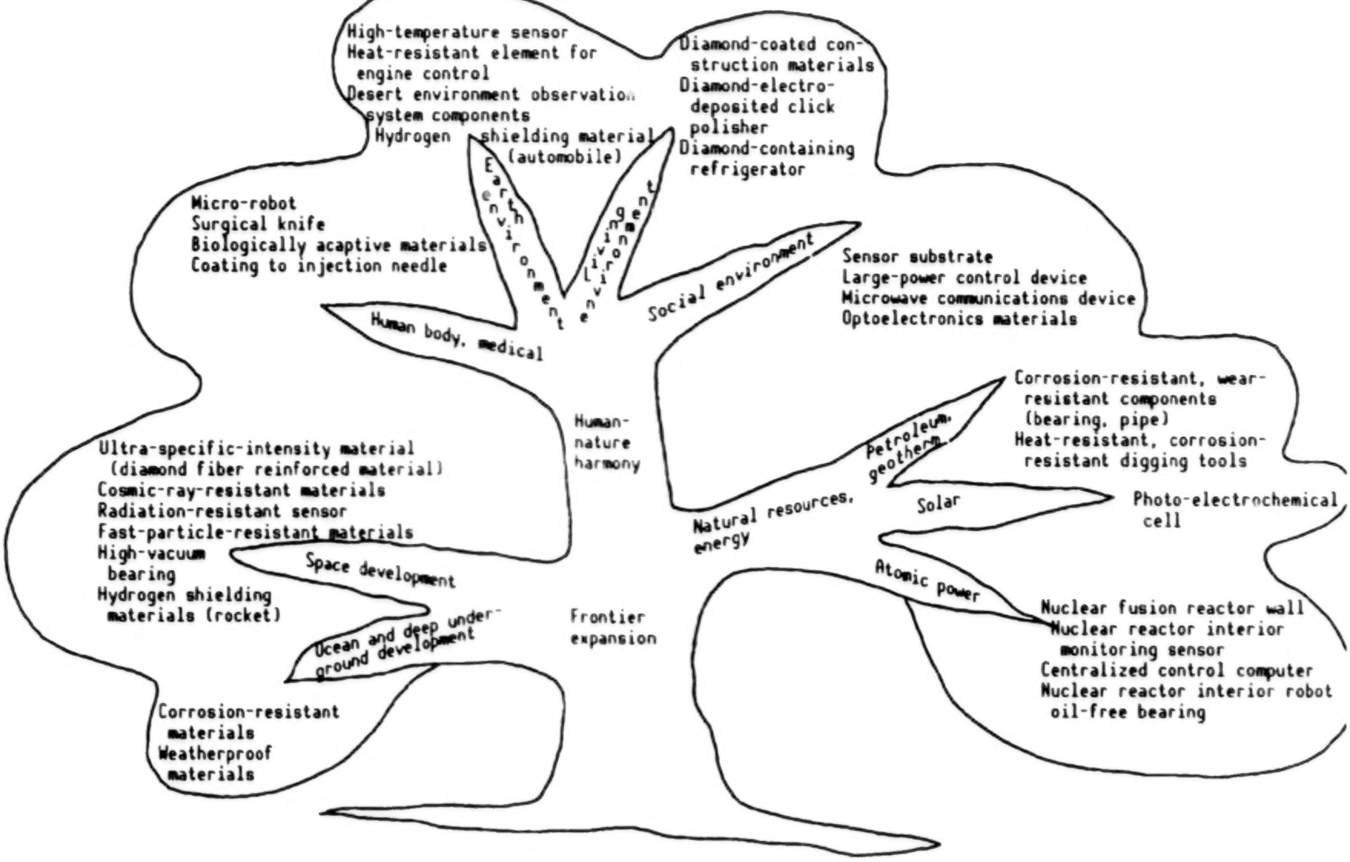
Linkage with user industries

Database, standardization (test and evaluation method, etc.)

4. Positive Promotion of International Cooperation



Prediction of Market Scale for New Diamond Industry-Related Products



Needs for Future Industries and Technologies Required To Be Developed—Possibilities of Diamond Application

Expected Fields for Diamond Application and Problems

Industrial field	Applied parts, device	Characteristics of use: Machine	Heat	Electronics	Optics	Chemistry	High energy resist beam	Final application technology, system	Principal technological problems
I. Earth environment	1. Ultraviolet sensor		o	o	o		o	Ozone concentration observation system	(1) High-purity diamond synthesis (2) Gold-diamond junction (3) High-density integration
	2. Heat-resistant device		o	o				Engine control system [Automobile, Airplane, etc.]	(1) Large-area single-crystal diamond synthesis (2) Method of manufacturing devices with semiconductor characteristics at high temperature
	3. Corrosion-resistant, wear-resistant components	o	o	o		o		Desert environment observation system	(1) Coating technology (large area, bond strength, fineness, work under bad environment)
	4. Hydrogen-shielding materials	o				o		Hydrogen fuel automobile	(1) Coating technology (large area, bond strength, fineness)
II. Living, social environment	1. High-output device	o	o	o				Large-power control system	(1) n-type semiconductor resistance control (2) pn junction (3) Single-crystal diamond heteroepitaxial growth on cheap materials
	2. High-output device substrate	o	o						(1) Area increasing, (2) Low-temperature high-speed film making, (3) Metallization adhesion, (4) High-purity diamond synthesis (reduce isotope 13C)
	3. Surface elastic-wave device	o	o	o				Satellite, vehicular communication equipment	(1) Manufacture smooth, few-crystal-defects diamond substrate (2) High-accuracy piezoelectric thin film and electrode on diamond substrate formation
	4. Biologically adaptive materials	o				o		Surgical knife, dental materials, etc.	(1) Processing technology (edging, edge polishing, etc.) (2) Coating technology (temperature lowering, direction control, etc.)
III. Frontier environment	1. Infrared parts	o			o		o	Space shuttle	(1) Area increasing ($100-$1,000) (2) High-speed film making technology (2,100 μm/h) (3) Strength raising
	2. Ultrahigh specific-intensity materials	o					o	Space observation system; Space station	(1) Diamond fiber manufacturing technology (2) Compounding technology
	3. Cosmic-ray-resistant materials	o					o	Artificial satellite	(1) Size increasing (2) Strength raising
	4. Fast-particle resistant materials	o					o	Planetary probe	(1) Size increasing (2) Strength raising
	5. High-vacuum low-friction materials	o					o	Bearing, mechanical seal, etc.	(1) Coating technology (adhesion, fining) (2) High-accuracy processing technology
	6. Corrosion-resistant, weatherproof components	o				o		Marine structures	(1) Coating technology (in water, on rust)
IV. Natural resources, energy	1. Radiation-resistant sensor			o			o	Nuclear reactor interior monitoring system	(1) High-purity diamond synthesis (2) Diamond and dissimilar materials junction technology

Trend of New Diamond Research and Development

<First phase>

1955 Artificial diamond (new diamond) synthesis by superhigh-pressure synthesis method

1955~75 New diamond development and application (Diamond-cBN grindstone, cutting tool, die, etc., using sintered diamond)

(Temporarily calmed due to oil crisis, etc.)

<Second phase>

1981 Synthesis by chemical vapor deposition (CVD) method at the National Institute for Research of Inorganic Materials

1980~ New diamond development by the CVD method and its application (Speaker diaphragm, cutting tool, bonding tool, etc., in which mainly structural characteristics were applied)

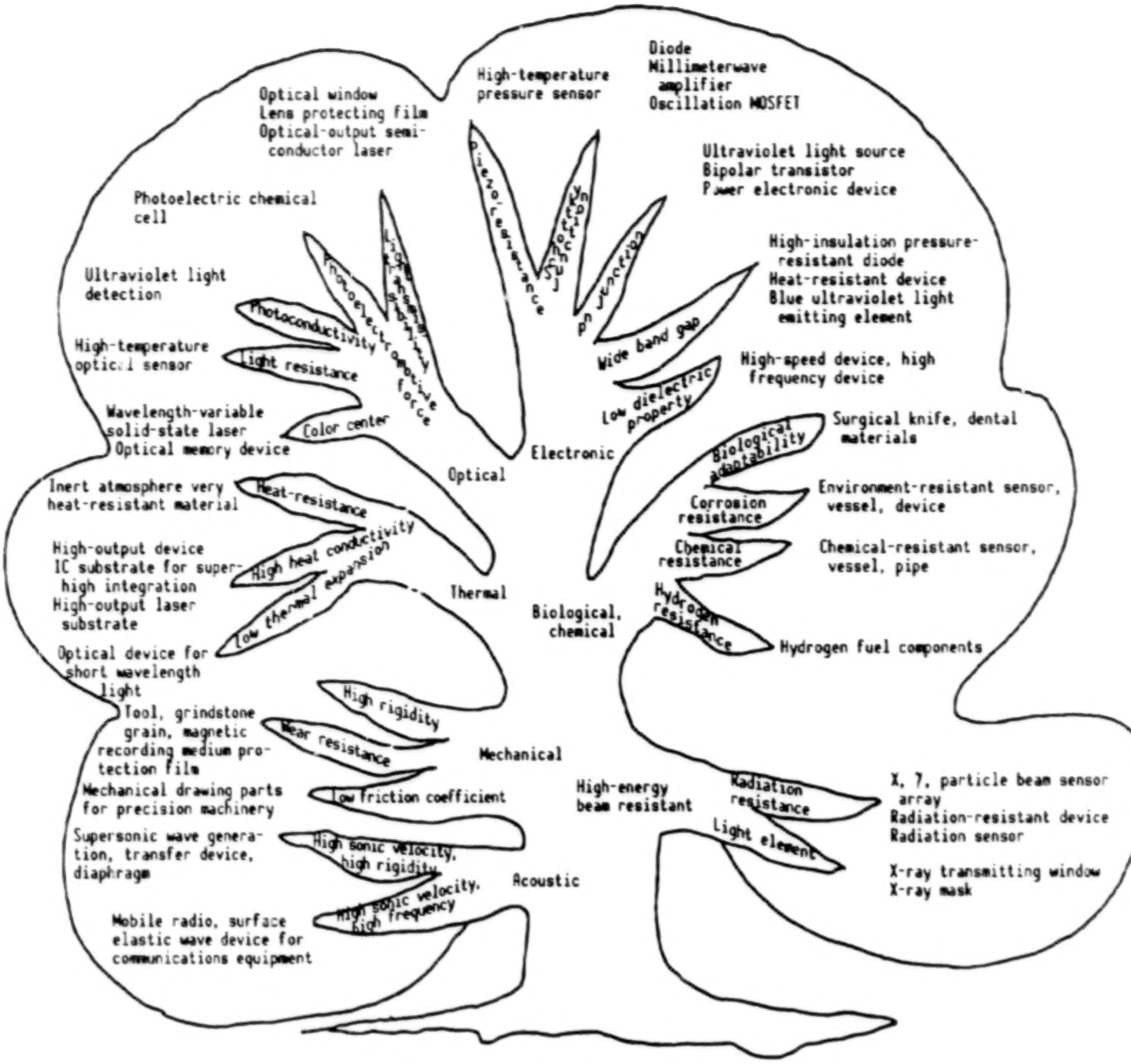
(Progress in atom- and molecular-level control technology)

<Third phase>

1990~ Challenge in functional diamond technology

Comparison of Typical Physical Properties Between Diamond and Various Materials

			Diamond	Si	cBN	SiC	GaAs
Physical properties	Symmetry		Diamond type (Fd3m) Hexagonal diamond type (P63/mmc)	ZB type Amorphous	ZB type (F43m) WZ type (C6mc)	ZB type WZ type Polytype	ZB type
	Lattice constant (Å)		3.567Å (Cubic) a=2.52Å, c=4.12Å (Hexagonal)	5.4307Å	3.615Å	4.3596Å (3C) a=3.0763Å, c=5.048Å (2H)	5.653Å
	Bond distance (Å)		1.544	2.352Å	1.565Å	1.888Å	2.488Å
	Bond energy (Kcal/mole)		85.4	54.5		73.9	38.9
	Density (g/cm³)		3.52	2.30	3.49	3.10	5.32
	Thermal expansion coefficient ($\times 10^{-6}$ deg^{-1})		2.3	4.2	3.7	3.7	6.5
Mechanical characteristics	Hardness	Mohs	10	7	9.5	9	
		Knoop (Kgf/mm²)	7,000~10,000		4,500~4,800	1,875~3,980	
	Young's modulus (MPa)		7.86	2.0	5.2	4.0	
	Poisson ratio		0.20		0.2	0.2	
Heat characteristics	Specific heat (Cal/g·deg)		0.122	0.180	0.121	0.17	0.038
	Heat conductivity (Cal/cm·s·deg)	25℃	5.0	0.36	1.4	0.65	0.13
		100	3.1	0.26	1.6	0.48	0.09
Electronic (electric) characteristics	Band gap (eV)	Direct	7.4	3.4	8.4	6.0	1.4
		Indirect	5.4	1.1	6.4~7	2.3	1.8
	Mobility (cm²/V·s)	Positive hole	2,100	450		70	420
		Electron	2,000	1,500		450~1,000	8,500
	Dielectric constant (at 1 MHz)		5.7	12	6.5	10	13
	Specific resistance (Ω·cm)		10^{16}	2×10^{5}	10^{11}		10^{8}
Optical character.	Refractive index		2.4195	3.448	2.117	2.65~2.69	3.4



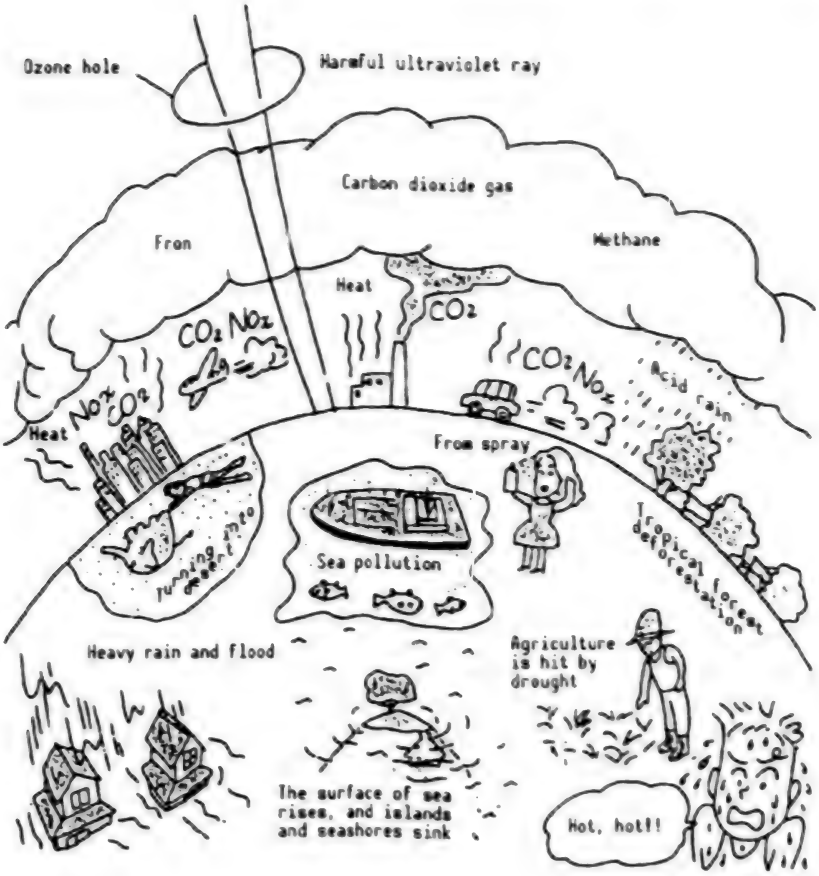
Material Characteristics Required From Future Technology and Promising Fields of Diamond

Technical Problems for Diamond Applications and Results of Evaluation of Their Degrees of Difficulty

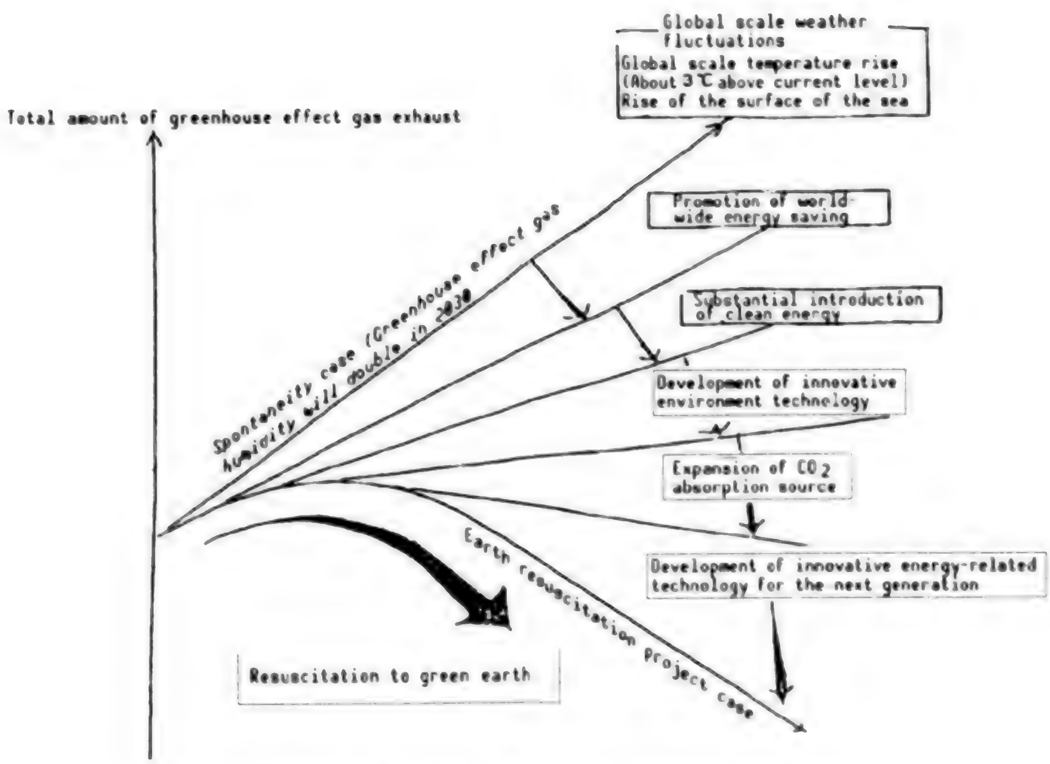
Classification	
A	Starting from constructing fundamental scientific knowledge is necessary.
B	There is fundamental scientific knowledge, but drastic ideas are necessary for producing technologies.
C	There are ideas considerably, but a wide range of systematic research is necessary for establishing technologies.
D	It is enough to push on a business competition basis.

Field	Parts	Technical problems		Degree of technical difficulty A	B	C	D	Remarks
I	1	(1)	Purity raising			O		
		(2)	Junction		O			
		(3)	Density increasing	O	O			
	2	(1)	①Single crystal	O				
			②Polycrystal			O		
		(2)	High-temperature operating semiconductor, et al.		O	O		~600℃
	3	(1)	① Coating (Large area)				O	
			② Coating (Bond strength)				O	
			③ Coating (Fineness)				O	
	4	(1)	① Coating (Large area)				O	
			② Coating (Bond strength)			O		
			③ Coating (Fineness)			O		
II	1	(1)	n type	O				
		(2)	pn junction		O			
		(3)	Heteroepitaxial growth		O			
	2	(1)	Area increasing				O	Polycrystalline products will do.
		(2)	Film making Low temperature High		O	O		Several 100 μm~mm order
		(3)	Metallization		O	O		
		(4)	High purity (low temperature °C)			O		
	3	(1)	Smooth, flawless			O		2~3GHz diamond substrate
		(2)	① Manufacturing technology, piezoelectric thin film making			O		
			②Electrode			O		
	4	(1)	Precision processing				O	
		(2)	Coating				O	
III	1	(1)	Large area				O	φ100~φ1000 (mm) Polycrystal will do
		(2)	High-speed film making				O	>100 μm/h
	2	(1)	Diamond fiber		O			
		(2)	Compounding		O			High heat conduction, lightweight
	3							Same as III-2
	4							Same as III-w
	5	(1)	Coating		O			Curved surface coating technology
		(2)	Film thickness precision control		O			
		(3)	High-precision processing		O			Several nm
	6	(1)						
IV	1	(1)	Purity raising			O		
		(2)	Junction		O			

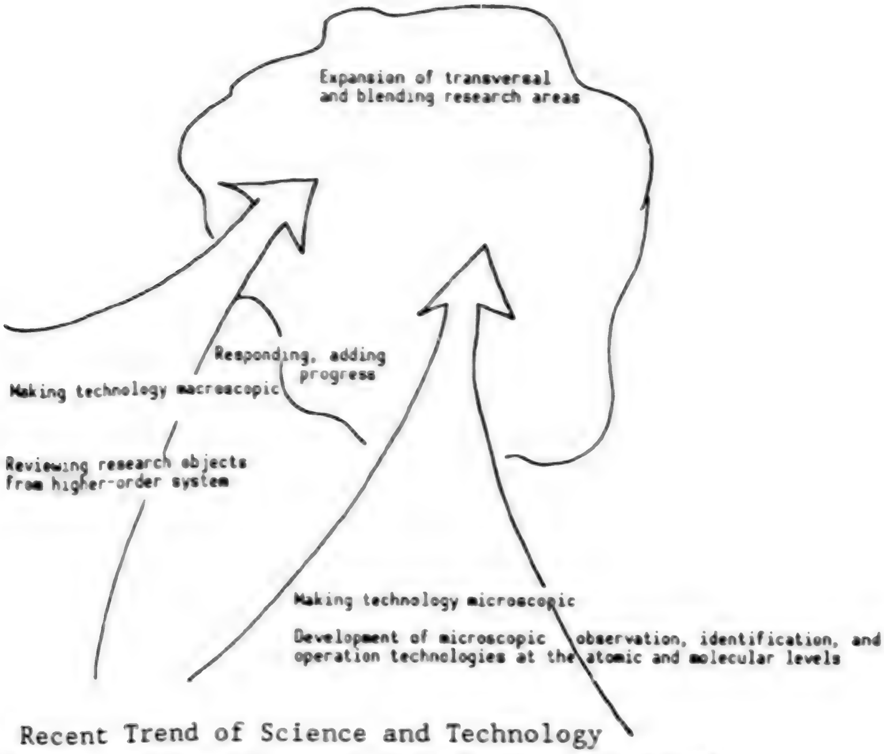
Note: For the field, parts and technical problems, see Table 4-2 "Expected Fields for Diamond Application and Problems."



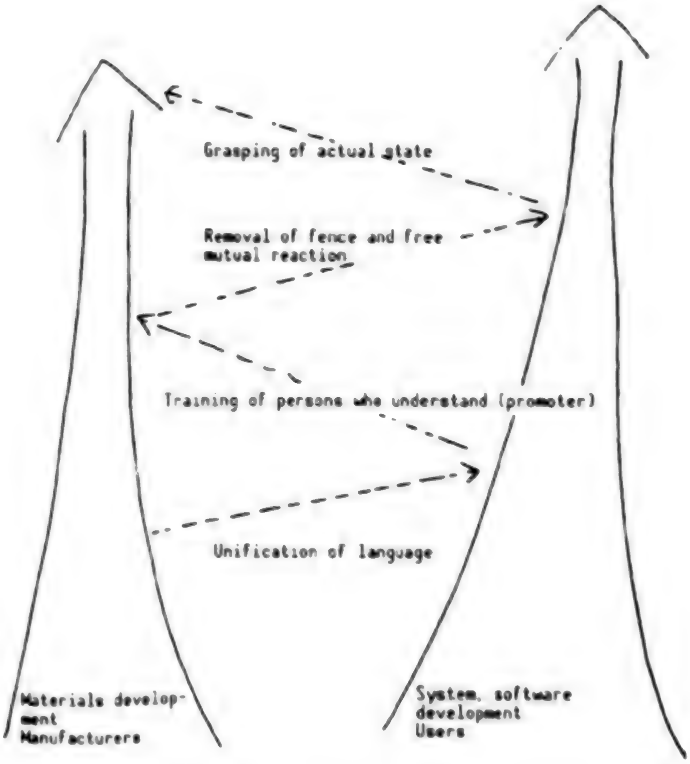
The Earth Is Weeping



Conception of "Earth Resuscitation Project"



Recent Trend of Science and Technology
(Establishment of New Science and Technology Division)



For Development of Materials Science

International Trend Over New Diamond

1. The United States

Even recently, the number of research groups is increasing (about several tens), well balanced with fundamental research.

(1) Material Research Laboratory/Pennsylvania State University
(2) Department of Material Engineering/North Carolina State University
(3) Department of Chemical Engineering/Case Western Research University
(4) Naval Research Laboratory
(5) Special Materials Department and R&D Center/General Electric Company
(6) Diamond Research Laboratory/Norton Company

2. Europe

The CVD method is used by several groups.

(1) London University (London, England)
(2) Croeckner-Wilhrmsburger (Germany)

3. The Soviet Union, East Europe

(1) Institute for High Pressure Physics (Moscow, Soviet Union)
(2) Institute for Superhard Material, Kiev (Kiev, Soviet Union)
(3) Institute for Physical Chemistry (Moscow, Soviet Union)
(4) Institute for High Pressure Academic Science (Potsdam, Germany)
(5) Institute for Electronic Materials Technology (Warsaw, Poland)

4. China, Asia

(1) Shanghai Silicate Research Institute
(2) Chengtu Science and Technology University
(3) Atomic and Molecular Physics Laboratory, Chilin University
(4) KAIST (Republic of Korea)
(5) National Physical Laboratory (India)

Approach to New Materials R&D

916C3809B Tokyo NEW DIAMOND FORUM: ABSTRACTS OF LECTURES AT 6TH GENERAL SESSION SPECIAL LECTURES in Japanese Jun 91 pp 1-31

[Article by Yuichi Maezawa, Materials Development Promotion Office chief, Research and Development Bureau, Science and Technology Agency: "Approach to New Materials Research and Development at the Science and Technology Agency"]

[Text] **Main Lines of Science and Technology Policy Decided Upon by Cabinet on 28 March 1986**

1. **Basic Policy**

• Science and technology of full creativity

• Harmonious development of science and technology and the human society

• Development of science and technology with stress on internationality

2. **Promotion of Priority Measures**

• Completion and strengthening of promotion system

• Completion and strengthening of promotion conditions

3. **Promotion of Important Research and Development Areas**

• Implementation of research and development with priority given to elementary and leading science and technology for various research and development areas

• The prime minister works out research and development programs in succession for every area that must be promoted on a priority basis

Report for Inquiry No. 14 Entitled "On the Basic Research and Development Programs for Substances and materials Science and Technology" of the Council for Science and Technology

Inquiry made on 27 May 1986
Inquiry made on 28 August 1987
Decided upon by the prime minister on 22 October 1987

Chapter 1. Basic Idea

Chapter 2. Principal Research and Development Goals

Chapter 3. Research and Development Promotion Measures

Basic Idea

(1) Contribution to Development of Economic Society

Foundation for developing other science and technology areas

Motive power for technical innovation toward the development of the human society in the 21st century

(2) Progress in Learning and Remarkable Development of Research Means

Atomic- and molecular-level control of substances and materials

Display of advanced functions through development of subtle processing technology, etc.

(3) Importance Attached to Elementary Research

1) Creation of substances and materials having innovative functions

2) Principle, phenomenon, and theoretical research that become the basis

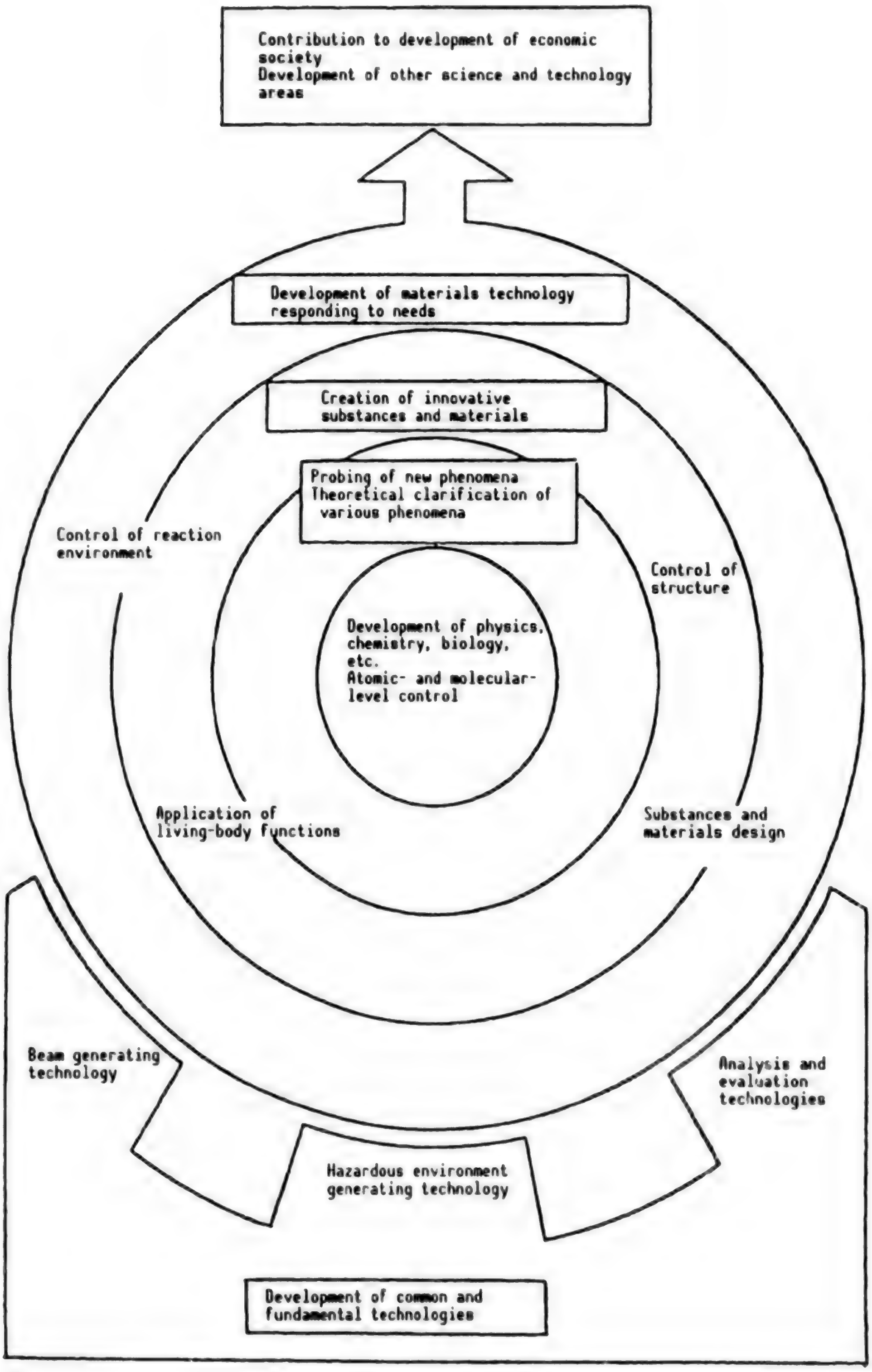
3) Development of more advanced common and fundamental technologies

(4) Advancing of Application Technology and Existing Materials

(5) Completion of Conditions

Strengthening of elementary research

Positively contributing to international society



Outline of Principal Research and Development Goals in the Report for Inquiry No. 14 of the Council for Science and Technology

Principal Research and Development Goals

Direction of research and development to be pushed with the next 10 years in mind.

1. **Probing of New Phenomena and Theoretical Clarification of Various Phenomena**

    Understanding of substances and materials to a greater extent of perfection at the microscopic level

2. **Creation of Innovative Substances and Materials**

    (1) Control of reaction environment

        1) Use of exciting beam
        2) Use of hazardous environment
        3) Control of reaction environments other than those mentioned above

    (2) Control of structure

        1) Hybridization
        2) Purity raising
        3) Composition coordination
        4) Crystal structure control
        5) Surface and interface control
        6) Control of structures other than those mentioned above

    (3) Application of living-body functions

        1) Use of biological substances and materials
        2) Use of substances and materials other than biological ones

    (4) Design of substances and materials

3. **Development of Materials Technology Responding to Needs**

    Development of materials having advanced functions needed for each of a wide range of areas

    Establishment of processing technology, reliability technology, etc.

4. **Development of Common and Fundamental Technologies**

    (1) Beam generating technology (including fine processing technology)

    (2) Hazardous environment generating technology

    (3) Analysis and evaluation technologies

Research and Development Promotion Measures

1. How To Promote Research and Development

(1) Elementary research—All research institutions promote various types of research according to their purpose by making use of their respective characteristics and striving for exchanges among themselves.

In that case, it is also necessary to conduct research as a project according to circumstances.

(2) Application development and research—Themes responding to concrete needs will be established, and promoted through pertinent sharing and cooperation among industrial, academic, and government research institutions.

2. Completion of Research and Development Promotion Conditions

(1) Training and securing of personnel, amplification of research expenses, etc.

Research will be evaluated properly, and a soil for training researchers created.

Researchers with superior creativity and international view of things will be trained and secured.

While considering preponderant and efficient distribution of research expenses, efforts will be made more to amplify them.

(2) Strengthening of research and development foundation

1) Acceleration of information distribution

a) Information on the results, etc., of research and development activities will be quickly distributed and efficiently used to the greatest possible extent.

Consideration will be paid to its offering abroad.

b) Amplification of fact database

With internationality taken into account, consideration will be given to standardizing the expression of data.

c) Completion of database networking

2) Completion of development and supply functions of equipment, materials, etc.

a) Smooth supply of specific experimental materials, standard substances, etc.

b) Advanced equipment and facilities, which the private sectors can hardly cope with, will be developed and completed through national efforts.

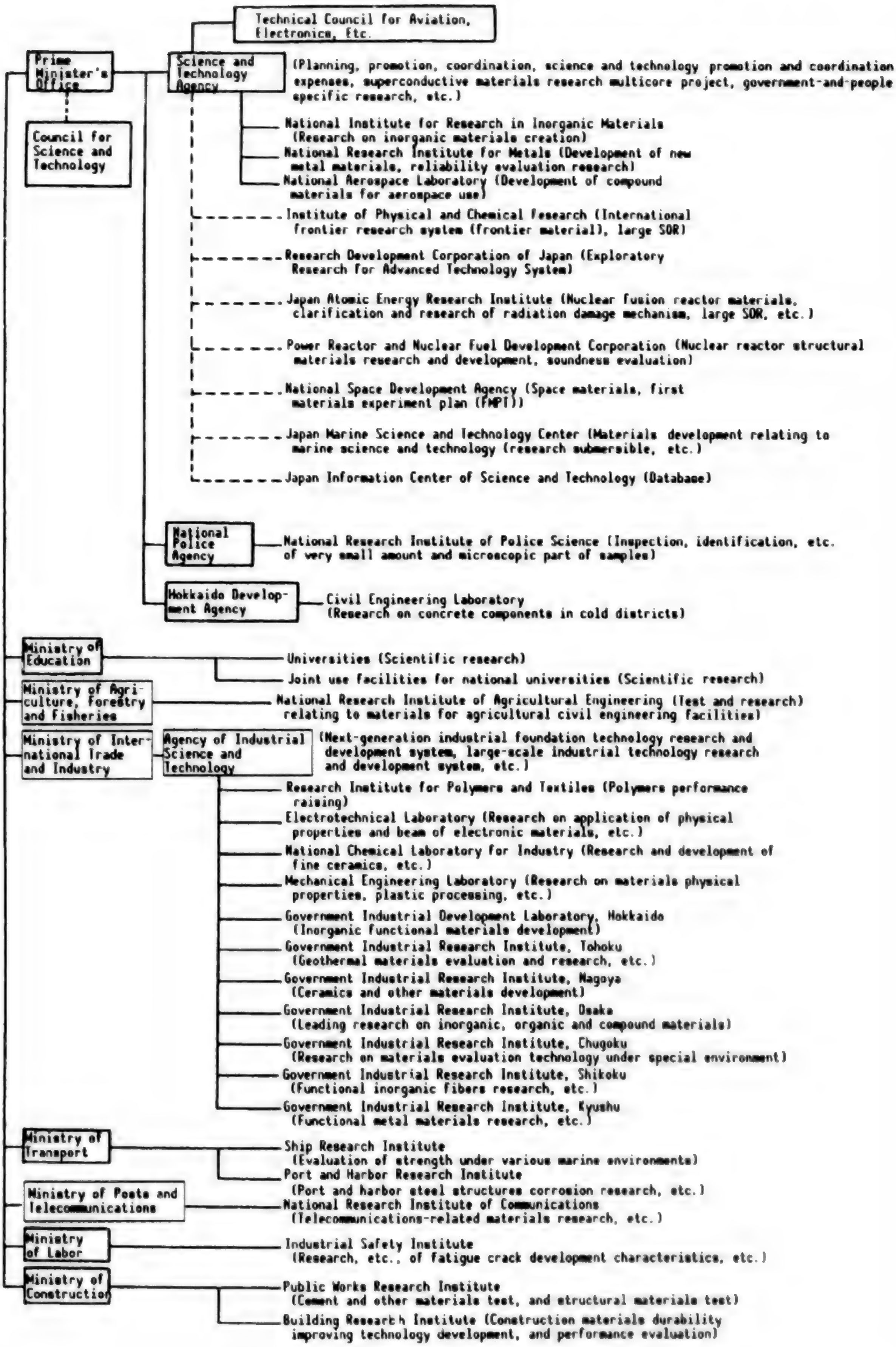
c) They will be efficiently and effectively used through such means as accelerating joint use.

(3) Promotion of international exchange and cooperation

1) Information exchange, international exchange of researchers, promotion of joint research, acceptance of foreign researchers, cooperation with developing countries, etc.

2) Pertinent response about research and development for which international sharing is required

Government Materials Research and Development Promotion System



ORGANIZATION

Nobuo Sedaka
director
Doctor of Eng.

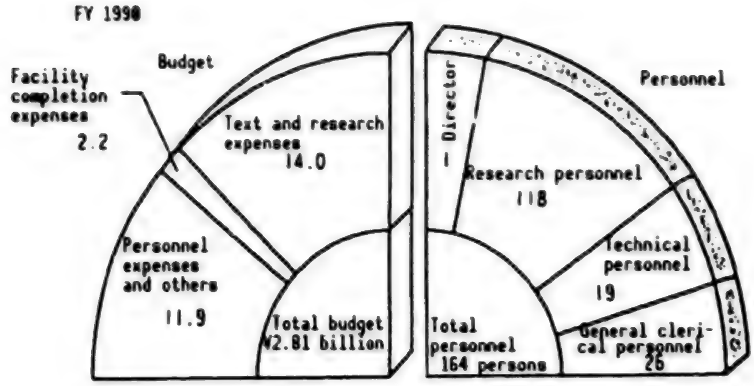
- Guest researchers
- Administrative Council
- Advisers

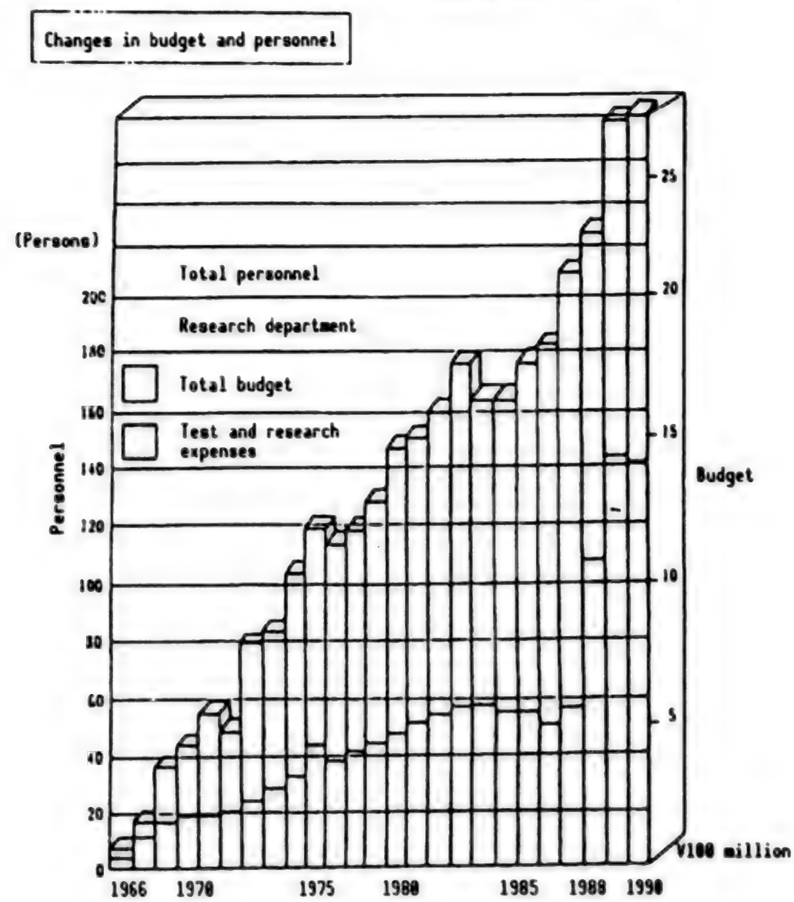
- Administrative Department
  - Mitsuo Hayashi, department chief
    - General Affairs Section
      - Masahiro Sekita, section chief
    - Accounts Section
      - Chiaki Tomita, section chief
    - Planning section
      - Shimuya Sakamoto, section chief
    - Technical Section
      - Shigehisa Konno, section chief
- 1st Research Group, Compound zirconium oxide
  - Shinichi Shiroyori, general researcher, Doctor of Eng.
- 2d Research Group, Compound tantalum sulfide
  - Norihiko Ishii, general researcher, Doctor of Science
- 3d Research Group, Silicon-radical nonoxide
  - Yoshizo Inomata, general researcher, Doctor of Eng.
- 4th Research Group, Bismuth-radical oxyfluoride
  - Shigeo Horiuchi, general researcher, Doctor of Eng.
- 5th Research Group, Copper perovskite
  - Satoshi Okai, general researcher, Doctor of Science
- 6th Research Group, Metallic typical element chalcogenide
  - Akira Era, general researcher, Doctor of Engineering
- 7th Research Group, Titanogallium acid chloride
  - Yoshinori Fujiki, general researcher, Doctor of Eng.
- 8th Research Group, Diamond
  - Yoichiro Sato, general researcher, Doctor of Science
- 9th Research Group, Tellurate glass
  - Akihiko Nukui, general researcher, Doctor of Eng.
- 10th Research Group, Niobic acid barium, sodium
  - Nobuo Sedaka, general researcher (concurrent service)
- 11th Research Group, Vanadium bronze
  - Katsuo Kato, general researcher, Doctor of Science
- 12th Research Group, Tungsten carbide
  - Yoshio Ishizawa, general researcher, Doctor of Science
- 13th Research Group, Rare earth garnet
  - Shigeyuki Kimura, general researcher, " " "
- 14th Research Group, Cobalt oxide
  - Toshinobu Chiga, general researcher, Doctor of Science
- 15th Research Group, Smectite
  - Hiromoto Nakazawa, general researcher, " " "
- Superhigh Pressure Station
  - Nobuo Yamaoka, general researcher, Doctor of Eng.
- Superhigh Temperature Station
  - Yusuke Moriyoshi, general researcher, Doctor of Eng.
- Unknown Substances Probing Center
  - Noboru Kimizuka, general researcher, Doctor of Science
- Special researcher

[continued]

[ORGANIZATION--continued]

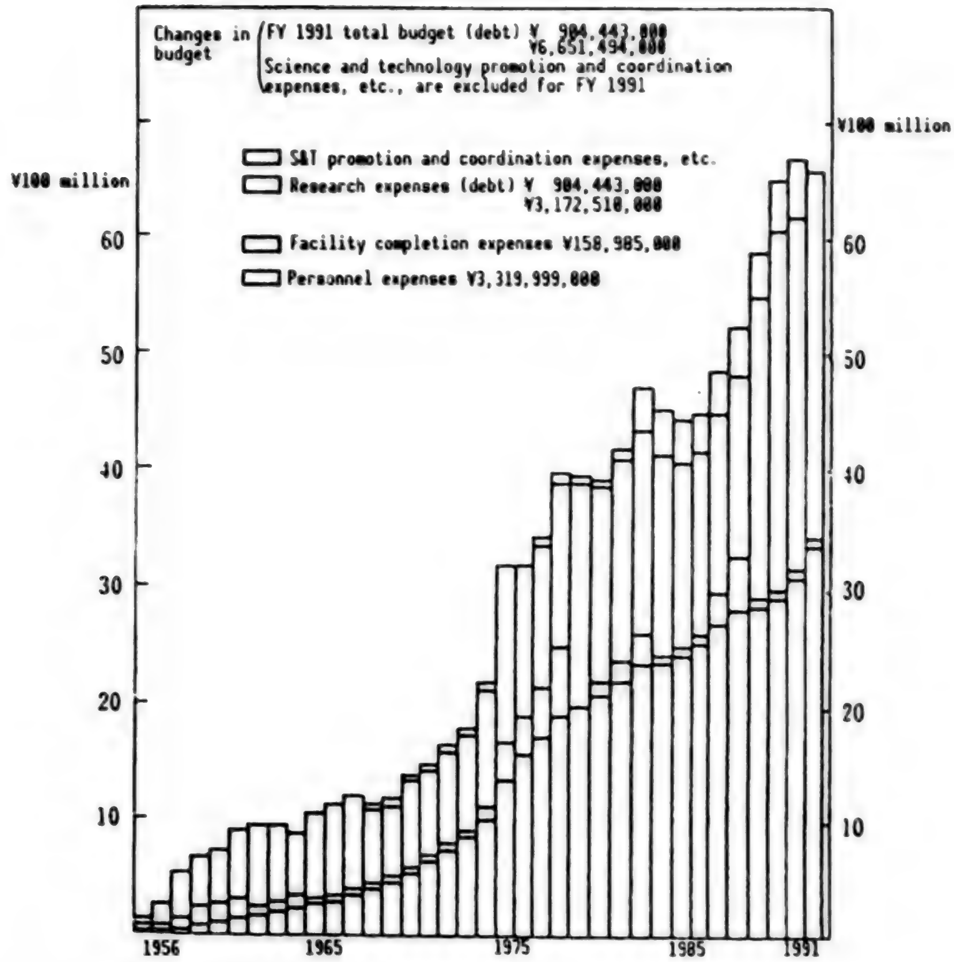
Advisers:	Ryoichi Kiriyama, professor emeritus, Osaka University Hideo Tagai, professor emeritus, Tokyo Institute of Technology Shunkichi Yamauchi, professor emeritus, Tokyo Institute of Technology
Adminis-trative Council members:	Kuniomi Umezawa, chairman, Technical Council for Aviation, Electronics, etc. Hiroshi Okuda, consultant, Fine Ceramics Center Foundation Mitsuyoshi Kouzumi, director, Science and Technology Joint Research Center, Ryukoku University Masaru Goto, managing director, Research Development Corporation of Japan Shinroku Saito, president, Nishi-Tokyo University of Science Ryoichi Sadanaga, member of the Japan Academy Sumio Sakuhana, director, Chemical Laboratory, Kyoto University Taira Suzuki, professor, Basic Engineering Department, Science University of Tokyo Hiroshige Suzuki, professor emeritus, Tokyo Institute of Technology Hirokichi Tanaka, former director, National Institute for Research of Inorganic Materials Kazuyoshi Arai, director, National Research Institute of Metals Fumiyuki Marumo, director, Industrial Materials Laboratory, Tokyo Institute of Technology



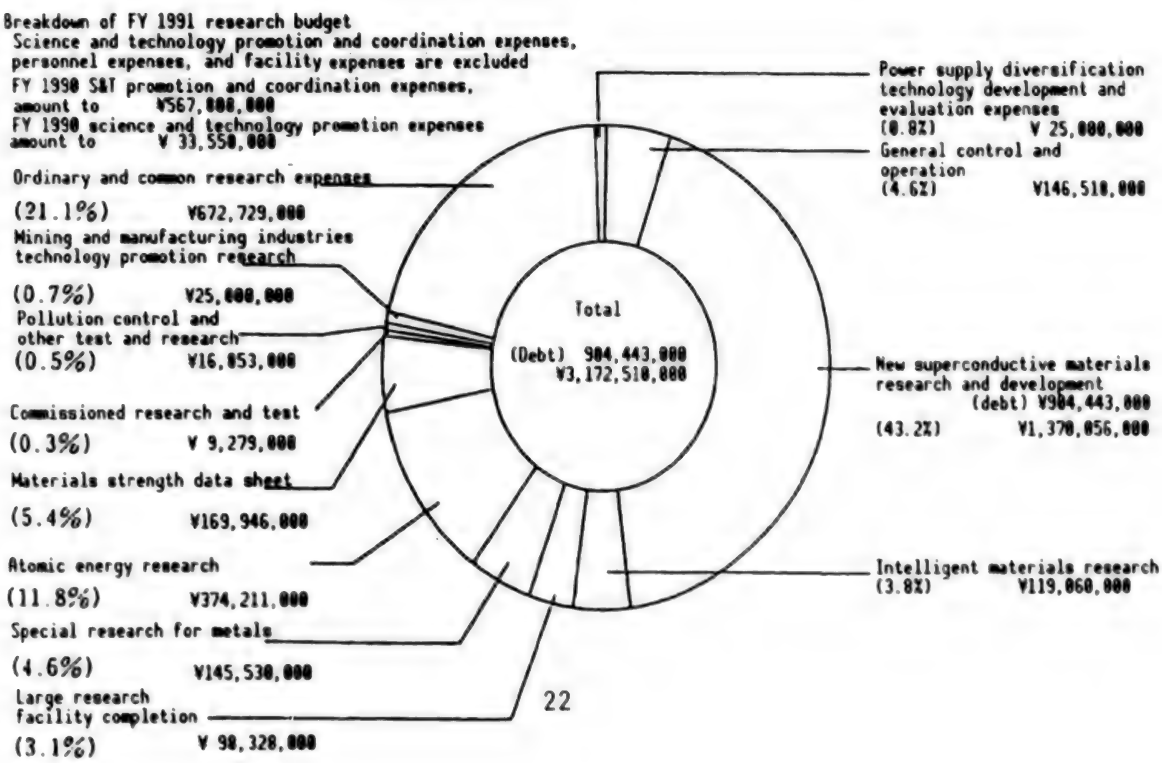


Budget, Personnel

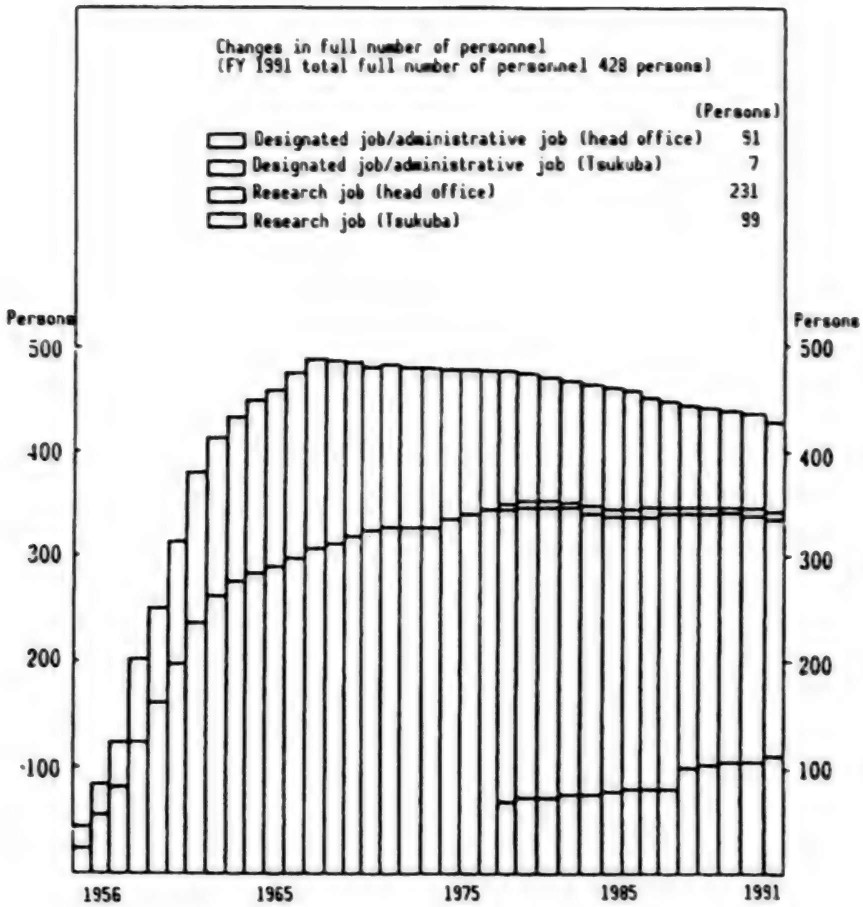
Budget



Changes in budget
FY 1991 total budget (debt) ¥ 904,443,000
¥6,651,494,000
Science and technology promotion and coordination expenses, etc., are excluded for FY 1991
¥100 million
¥100 million
S&T promotion and coordination expenses, etc.
Research expenses (debt) ¥ 904,443,000
¥3,172,510,000
Facility completion expenses ¥158,985,000
Personnel expenses ¥3,319,999,000
60
50
40
30
20
10
1956
1965
1975
1985
1991



Breakdown of FY 1991 research budget
Science and technology promotion and coordination expenses, personnel expenses, and facility expenses are excluded
FY 1990 S&T promotion and coordination expenses, amount to ¥567,000,000
FY 1990 science and technology promotion expenses amount to ¥ 33,550,000
Ordinary and common research expenses
(21.1%) ¥672,729,000
Mining and manufacturing industries technology promotion research
(0.7%) ¥25,000,000
Pollution control and other test and research
(0.5%) ¥16,053,000
Commissioned research and test
(0.3%) ¥ 9,279,000
Materials strength data sheet
(5.4%) ¥169,946,000
Atomic energy research
(11.8%) ¥374,211,000
Special research for metals
(4.6%) ¥145,530,000
Large research facility completion
(3.1%) ¥ 98,328,000
Power supply diversification technology development and evaluation expenses
(0.8%) ¥ 25,000,000
General control and operation
(4.6%) ¥146,510,000
Total
(Debt) 904,443,000
¥3,172,510,000
New superconductive materials research and development
(debt) ¥904,443,000
(43.2%) ¥1,370,056,000
Intelligent materials research
(3.8%) ¥119,060,000



Full Number of Personnel

Real Estate and Building

	Head office	Tsukuba branch	Total
Plot size	45,072 m^2	149,839 m^2	194,911 m^2
Building total floor space	37,063 m^2	10,309 m^2	47,372 m^2

"Science and Technology Promotion and Coordination Expenses"

Since the establishment of a state on the basis of science and technology is an important measure of the government, it is important that the Council for Science and Technology, which is Japan's supreme deliberative organ on science and technology policy, strengthen its functions of general coordination on the basis of its great insight and view of things and play a leading role in the science and technology policy. In view of this fact, these expenses have been set for taking measures to comprehensively promote and coordinate important research activities in line with the policy of the Council for Science and Technology.

Six-Item Basic Policy

(1) Promotion of advanced and elementary research.

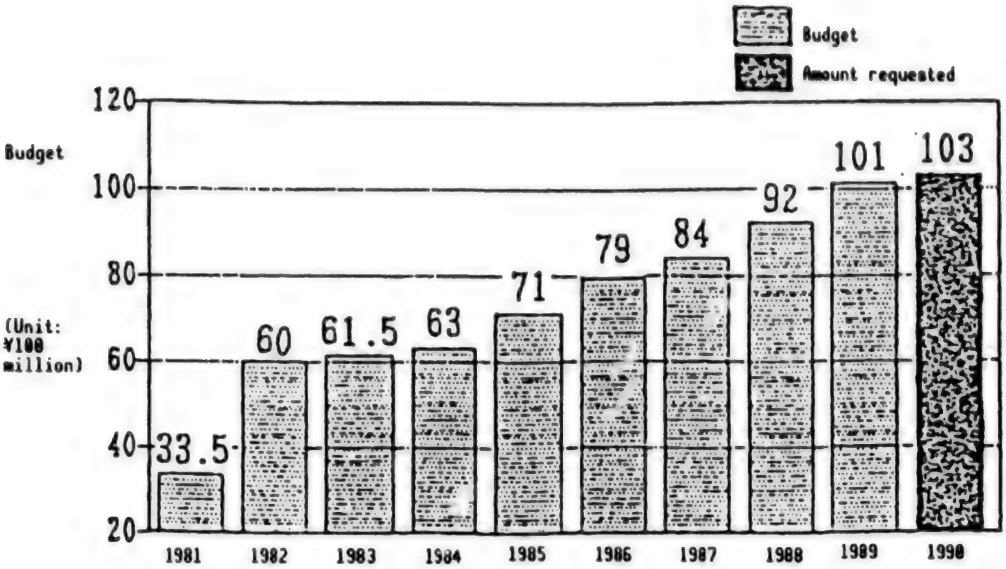
(2) Promotion of research and development that call for cooperation by multiple organizations.

(3) Strengthening of organic cooperation among industrial, academic, and government organizations.

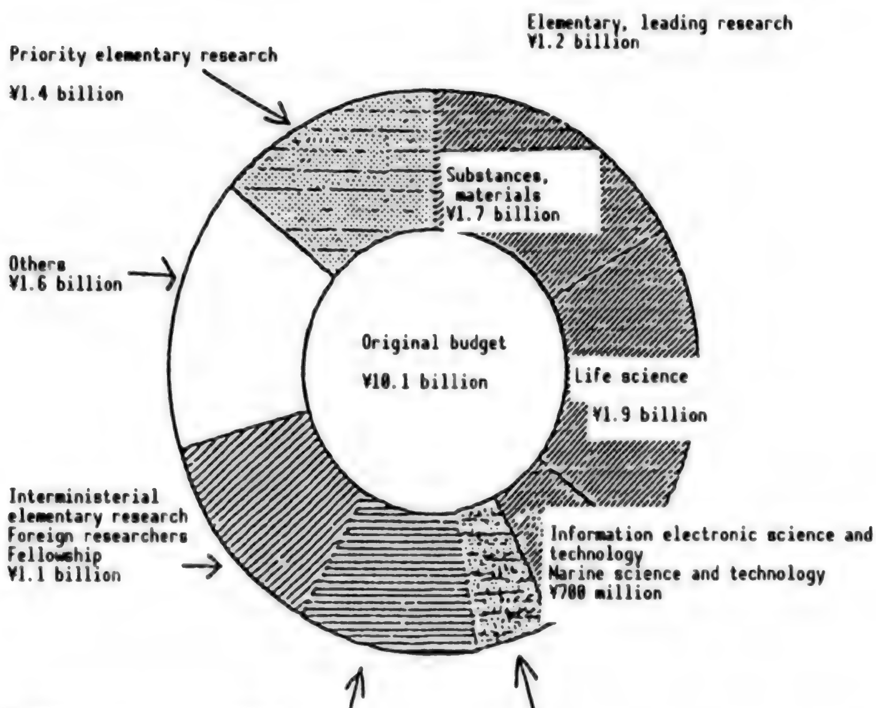
(4) Promotion of international joint research.

(5) Flexible response to instances where it becomes necessary to conduct research urgently.

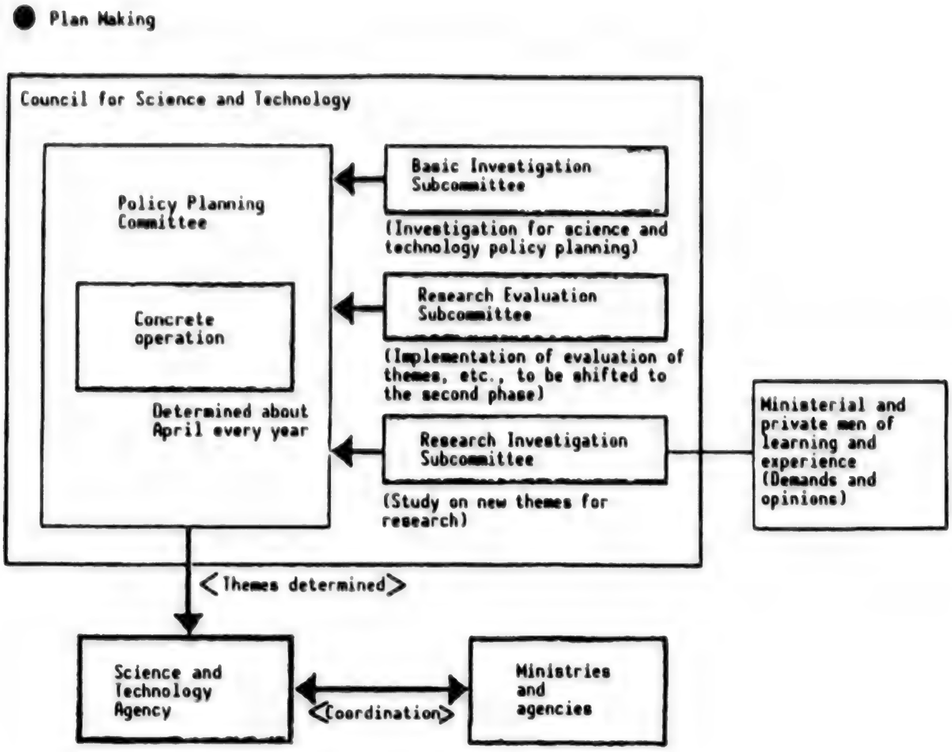
(6) Implementation of research evaluation and investigation and analysis of research and development.



Changes in Science and Technology Promotion and Coordination Expenses Budget

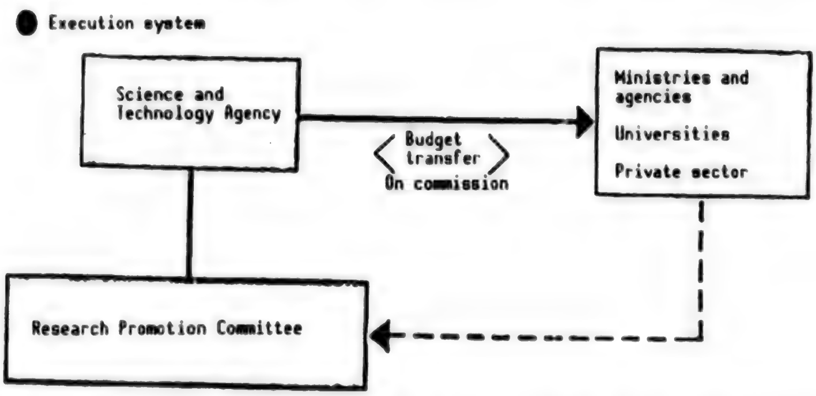


State of Operation of FY 1989 Budget (As of August)



Plan Making

Through Organic Cooperation Among Industrial, Academic, and Government Organizations Centering Around Research Promotion Committee



The research promotion committee, which comprises representatives of research conducting organizations and men of learning and experience, is established for every theme, and liaison and coordination are conducted with regard to important matters for research promotion.

Themes for Science and Technology Promotion and Coordination Expenses
(Substances and materials science and technology area)

(Unit: ¥1 million)

Description of theme	
	(Budget covers from program start to FY 1990)
(1) Research on analysis and evaluation technology using new beam technology for high-performance functional materials (FY 1986~	1,940)
(2) International joint research on new materials test and evaluation technology (FY 1986~	758)
(3) Research on fundamental technology for creating new functions by purity raising of rare metals (FY 1987~	1,126)
(4) Research on fundamental technology for functionally gradient materials development for decreasing thermal stresses (FY 1987~	1,034)
(5) Research on development of extremely high vacuum generation, measurement, and utilization technology (FY 1988~	651)
(6) Research on vacuum ultraviolet light generation and utilization technology (FY 1988~	704)
(7) Research on measurement, evaluation, and control of elementary functions in ultramicro area of substances and materials (FY 1989~	599)
(8) Research on database construction for superconductive materials research and development (FY 1989~	171)
(9) Elementary research on host and guest reaction practical use technology for new functional materials creation (FY 1990~	161)
(10) Research on fundamental technology for material interconnection by ideal surface creation (FY 1990~	141)

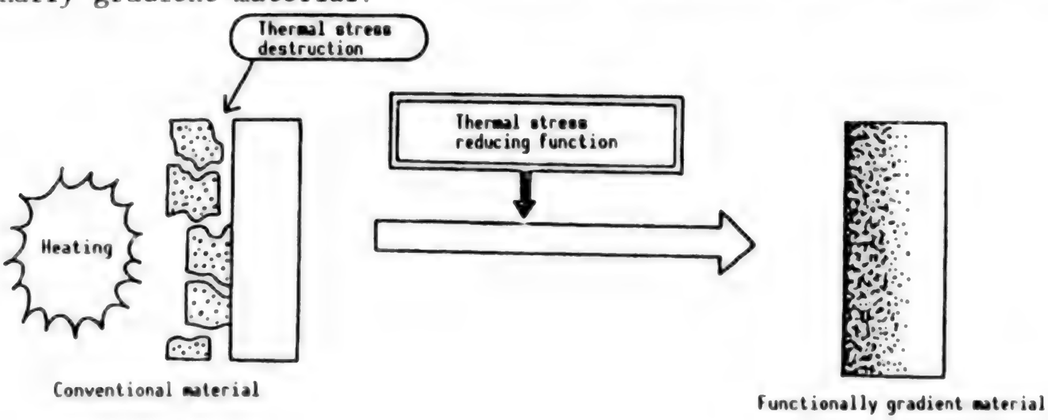
Science and Technology Promotion and Coordination Expenses News
Science and Technology Agency

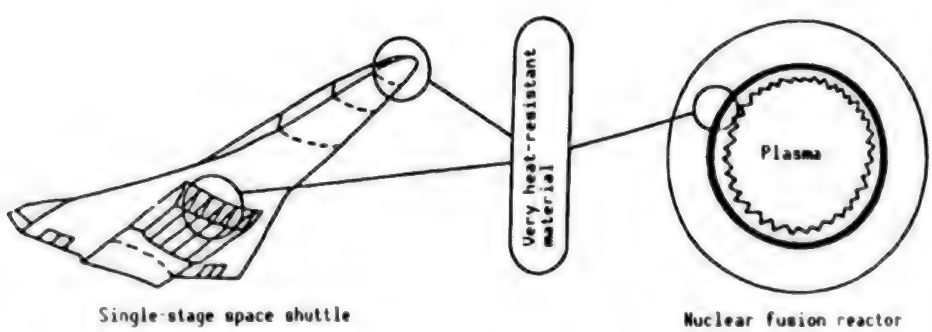
—No. 41—
23 August 1989

First Successful Creation of Various Functionally Gradient Materials

Since FY 1987, the Science and Technology Agency, under its science and technology promotion and coordination expenses, has been pushing a project entitled "Research on Fundamental Technologies To Develop Functionally Gradient Materials To Reduce Thermal Stress," with a view to developing very heat-resistant materials. This research is aimed at establishing fundamental technologies for creating the functionally gradient materials, which can be used under such environmental conditions as 1,700°C in maximum temperature and 1,000°C in maximum temperature difference, with the thermal protection system of a space plane, engine combustor walls or turbine blades, etc., as targets. As part of this research, through a project comprising domestic manufacturers and university and national laboratories, we have currently succeeded for the first time in the world in test manufacturing a 3-cm disk functionally gradient material that has been put up as the first-phase development target.

This material has been synthesized by controlling its internal composition and microstructure so as to form a continuous and optimal distribution for functional environment. This material has a specific high function that the distribution of its composition and structure is gradient, and is named the functionally gradient material.

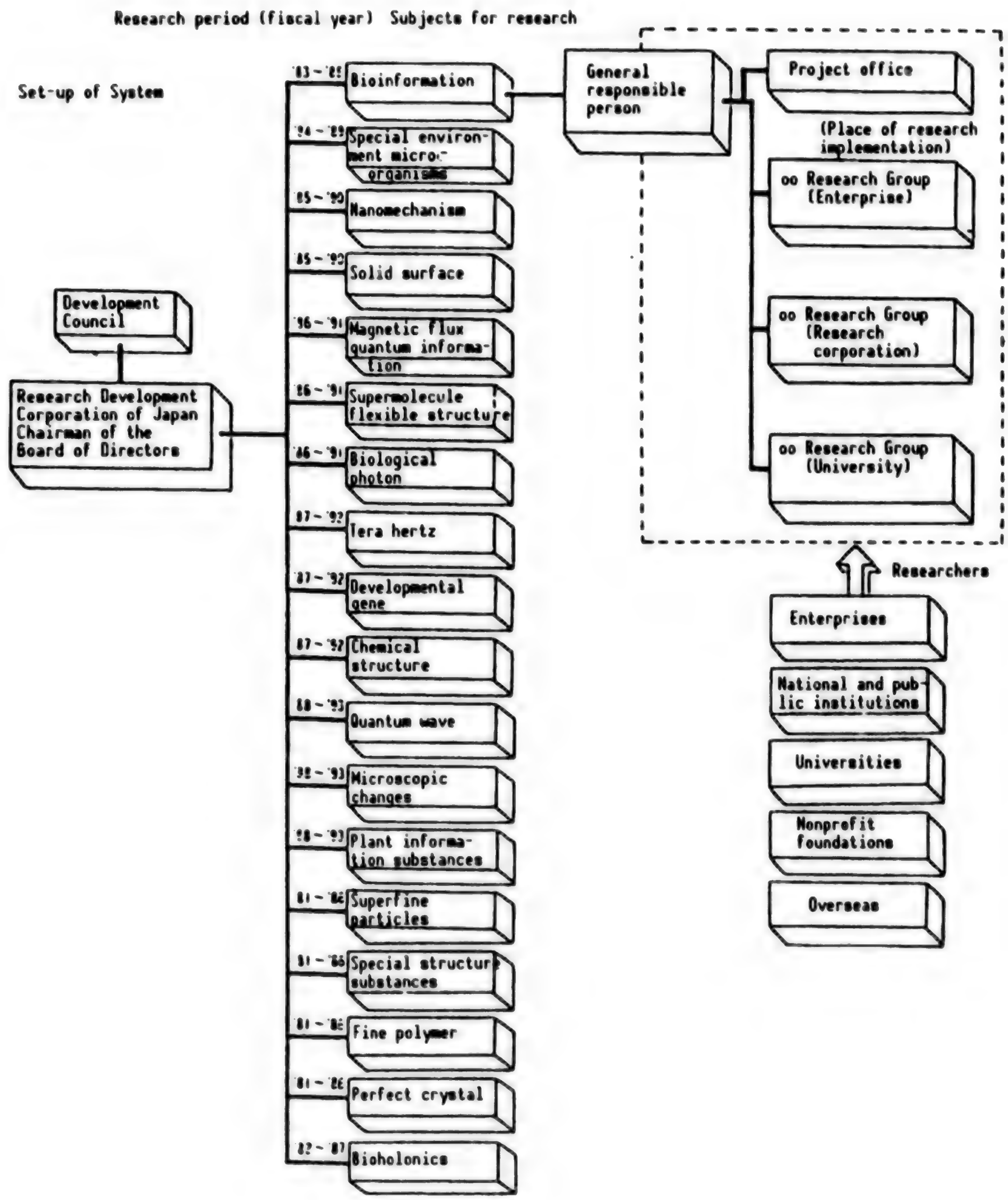


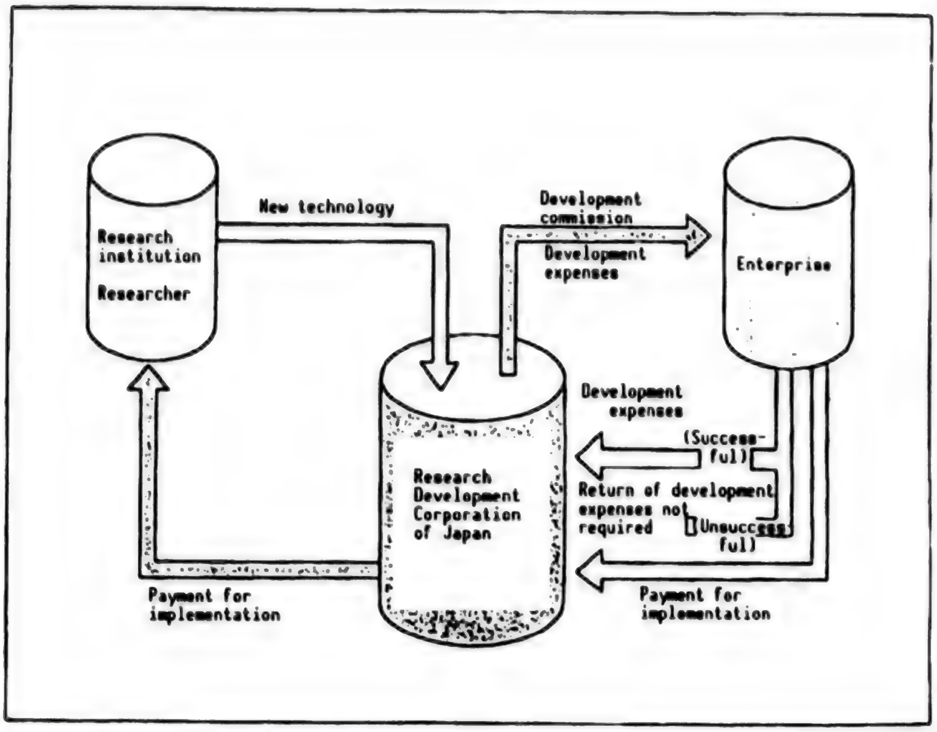


Exploratory Research for Advanced Technology

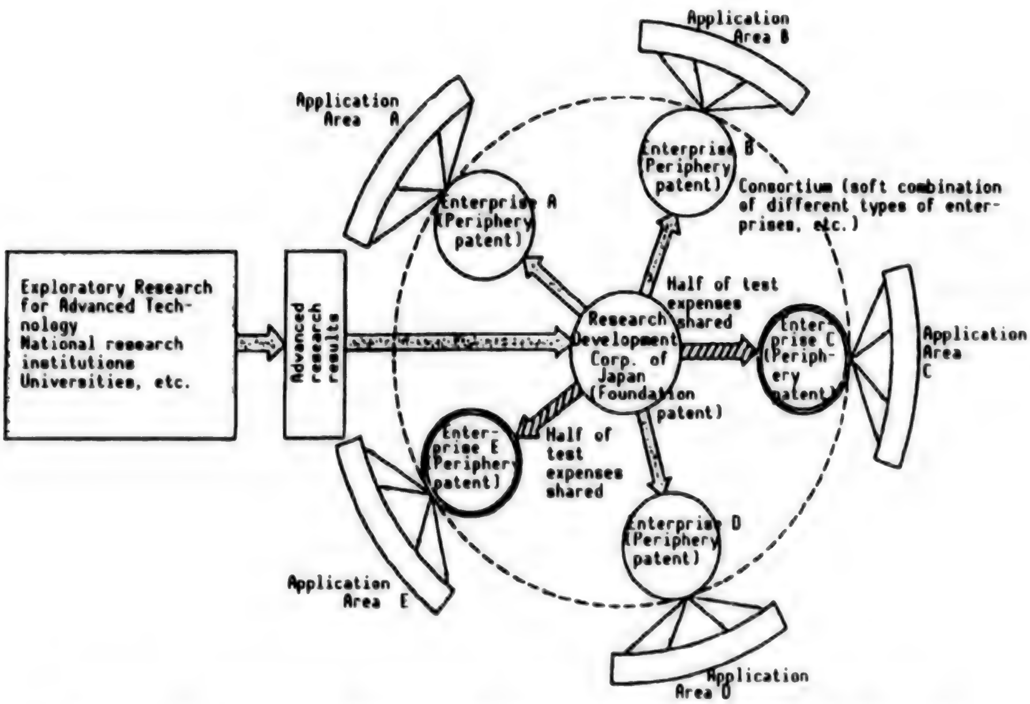
Purpose

This system is aimed at initiating a new idea from elementary research, which will become the source of future science and technology, and also at positively creating the bud of innovative technologies. Out of recognition that prominent individual ability and elastic research management are essential for creative research activities, thoroughly human-centered research setup and operating method have been contributed.





Setup of Commission Development System

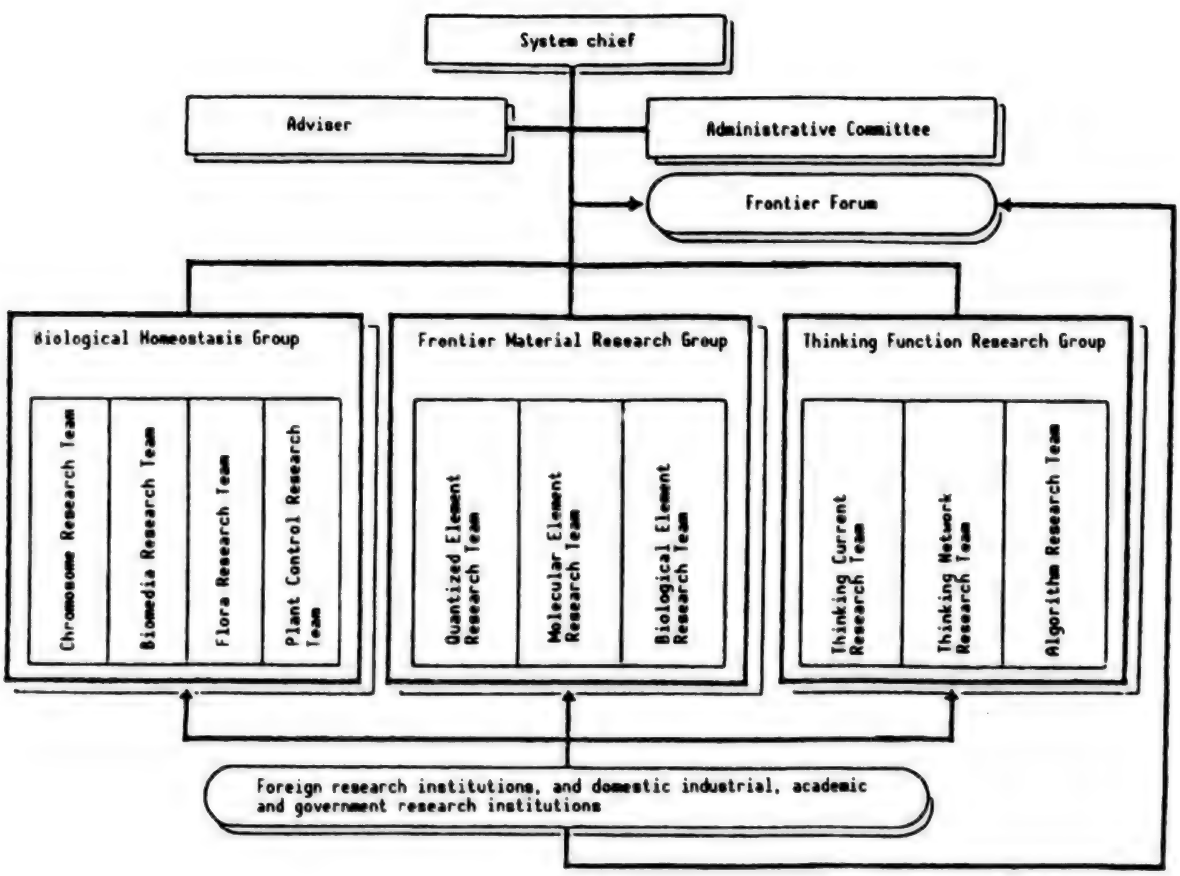


Setup of Advanced Technology Development Promotion System

International Frontier Research System

The international frontier research system is characteristic in that it conducts very advanced elementary research (frontier research) from a long-range standpoint by flowingly gathering researchers under an internationally opened system with a view to positively digging out new knowledge that could form the nucleus of technical innovation in the 21st century.

The international frontier research system will carry out research by providing a "research group" for each research area and posting "research teams" classified by research theme in each group under the leadership of a "system chief" who exercises general control over the research.



6. Budget

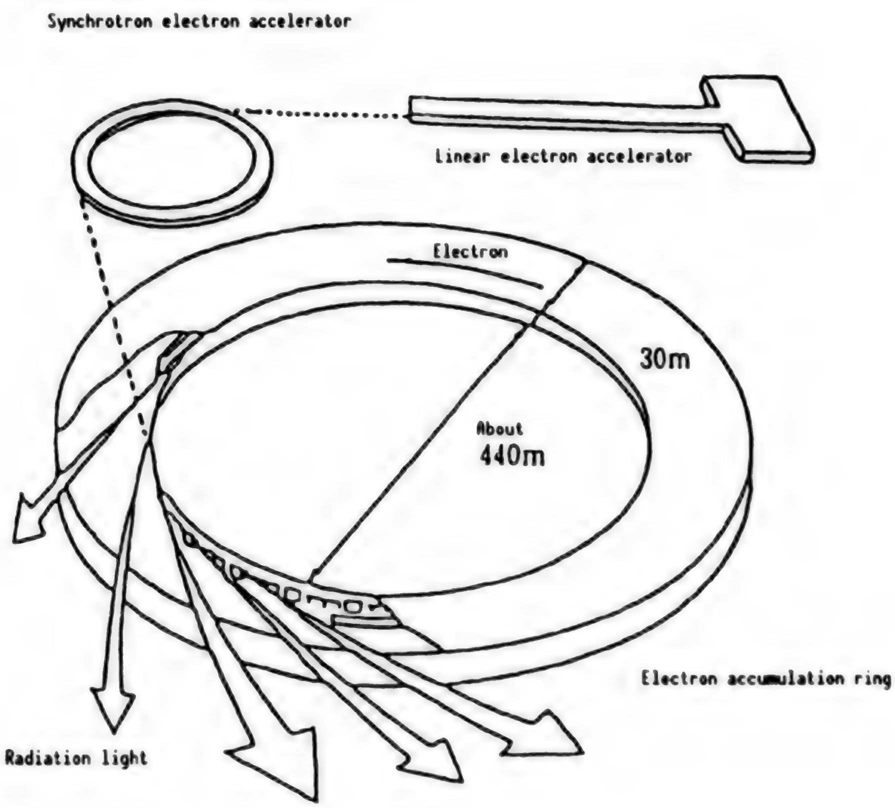
Unit: ¥ million

	FY 1991	FY 1990
Science and technology research foundation completion measures investigation expenses	4	(4)
(Intraministerial bureaus)	(Debt) 4,981	((Debt) 1,305)
		( )
Radiation light expenses, construction expenses (Institute of	2,733	(1,629)
Physical and Chemical Research)	(Debt) 3,304	((Debt) 994)
		( )
(Japan Atomic Energy Research Institute)	2,160	(1,167)
	(Debt) 8,285	((Debt) 2,299)
Total	4,896	(2,801)

(The total does not agree due to the calculation by rounding to the nearest whole number.)

(Total amount of main-body facility construction expenses are about ¥100 billion)

7. 8 GeV SOR Conceptual Diagram



8. Foreign Large Radiation Facility Projects

Project name	Place of facility	Energy	Scheduled completion	Remarks
APS (U.S.)	Argonne National Laboratory	7 GeV	1995	
ESRF (Europe)	Grenoble (France)	6 GeV	1994	Joint project by France, Britain, West Germany, Italy, Spain,

APS (Advanced Photon Source)
ESRF (European Synchrotron Radiation Facility)

List of Inquiries and Reports on Materials at the Technical Council for Aviation, Electronics, Etc.

Inquiry	Date of inquiry	Date of report	Outline
No. 5 "On Measures To Promote Comprehensive Research and Development on Hazardous Environment Science and Technology and Its Related Materials S&T"	13 May 79	28 Aug 80	Guideline for research on generation of such hazardous environments as very low temperature, ultrahigh temperature, ultrahigh pressure, and ultrahigh vacuum, and on creation, etc., of new materials using hazardous environments.
No. 7 "On Promotion of Comprehensive Research and Development on Creation of New Materials Based on the Materials Design Theory"	25 Jan 83	13 Sep 85	Guideline for research on theoretical foundation, materials design technology, structure control technology, analysis and evaluation technology, database, etc., as for materials design, the efficient materials development technique.
No. 9 "On Priority Themes for Advancing Measurement and Control Technology Relating to New Materials R&D, and Their Promotion Measures"	19 Mar 85	28 Mar 86	Guideline for research on measurement and control technology relating to creation of new materials, such as microscopic-level composition and structure analysis and advancing of control technology by use of beam technology, finding of new phenomena, and new measurement technique using such phenomena.

[Continuation of table]

Inquiry	Date of inquiry	Date of report	Outline
No. 11 "On Promotion of Comprehensive R&D on the Advancing of Optical Science and Technology"	15 Aug 86	14 Jul 87	Guideline for research on measures for advancing optical science and technology, such as laser beam and synchrotron radiation, technologies for using it for substances and materials, such as measurement and processing technologies using light, etc.
No. 13 "On Promotion of Comprehensive R&D on Creation of New Substances and Materials Capable of Functioning by Intelligently Responding to Environmental Conditions"	14 Jul 87	30 Nov 89	Guideline for research aimed at clarifying the concept of such matters as creation of new substances and materials having the so-called intelligent functions, such as environment adaptation function, self-repairing function, and self-multiplying function.
No. 16 "On Promotion of Comprehensive R&D on the Advancing of Analysis and Evaluation Technology Relating to Materials Development"	11 Mar 91	About half a year of deliberation scheduled	For promoting establishment and unification of new materials analysis and evaluation technologies under the efficient cooperation of the related organizations, deliberation is under way to acquire a guideline for research on the advancing of analysis and evaluation technologies relating to materials development.

On Report for "On Promotion of Comprehensive Research and Development on Creation of New Substances and Materials Capable of Functioning by Intelligently Responding to Environmental Conditions (Inquiry No. 13)

—Intelligent Materials—

Background, necessity

- Swelling of software in information society
  → Software built-into materials
- Capability limit of silicon-based semiconductors
  → Realization of (intelligent) information processing in materials
- Demands for materials that control themselves according to such living-body conditions as growth, cure, and condition of disease
- Demand for materials themselves to have self-diagnosing and self-repairing properties in such hazardous working environments as aviation, space, and atomic energy

Technical realizability

- Atomic- and molecular-level structure and function control
- Clarification and control of meso-scopic level (the level of massive group of about 100-10,000 atoms having specific properties) structure and function
- Biological function clarification and practical use of its results

⇩ ⇩

Creation of substances and materials based on new concept

Materials themselves make multiple responses according to changes in environmental conditions.

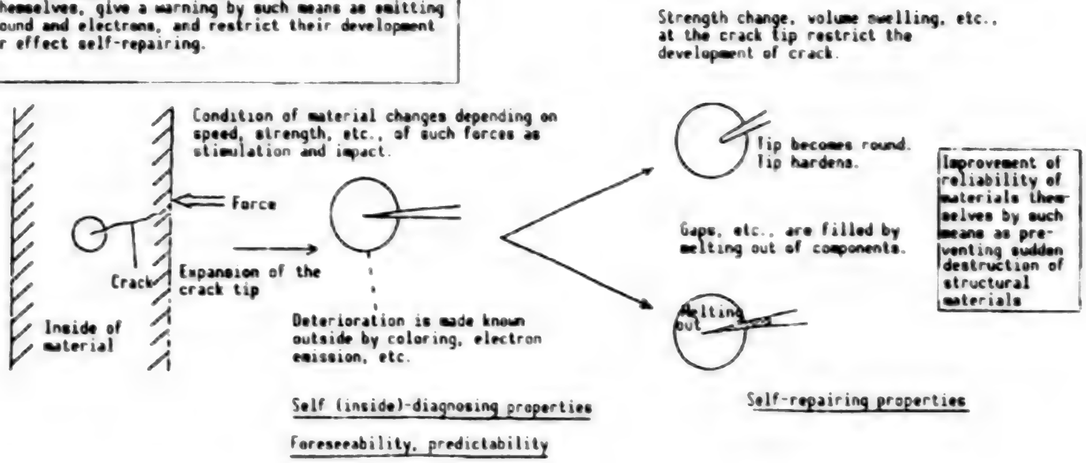
Multiple functions (functions of responding by feeling, memorizing, and judging environmental changes) are connected and microscopically realized in materials.

(Realization in materials of atomic- and molecular-level systems that feel, judge and work.)

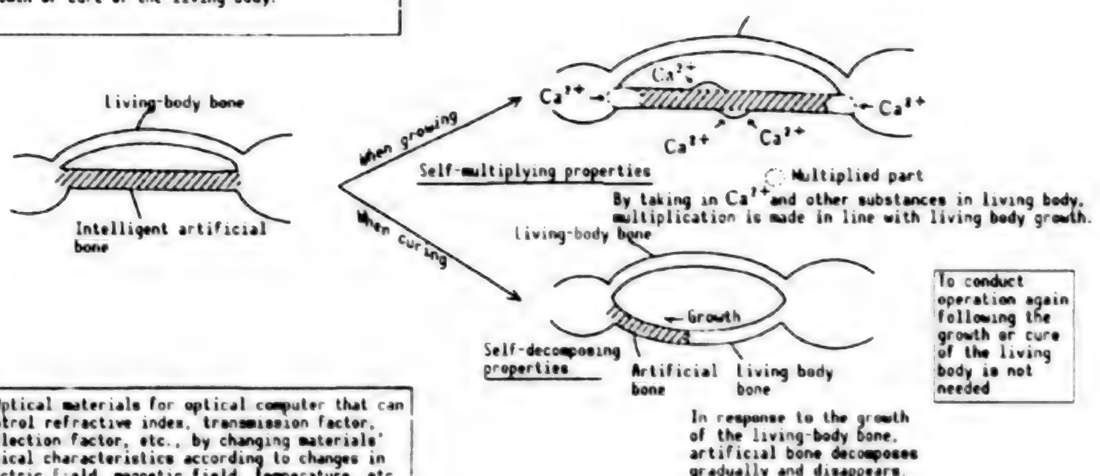
- Optical materials that change refractive index, transmission factor, reflecting factor, etc., according to environmental changes (Information, electronics area)
- Sensor and electronic materials that recognize multiple stimulations and make proper judgment according to changes in the environment conditions (Information, electronics area)
- Capsule materials that release medicines according to the body conditions (Medical area)
- Medical materials, such as veins and bones, that grow or decompose according to the situation of growth or cure of the living body (Medical area)
- Structural materials that foresee and prevent the development of cracks (Aviation, space, atomic energy area)

Aspect Wherein Intelligent Functions Are Fulfilled

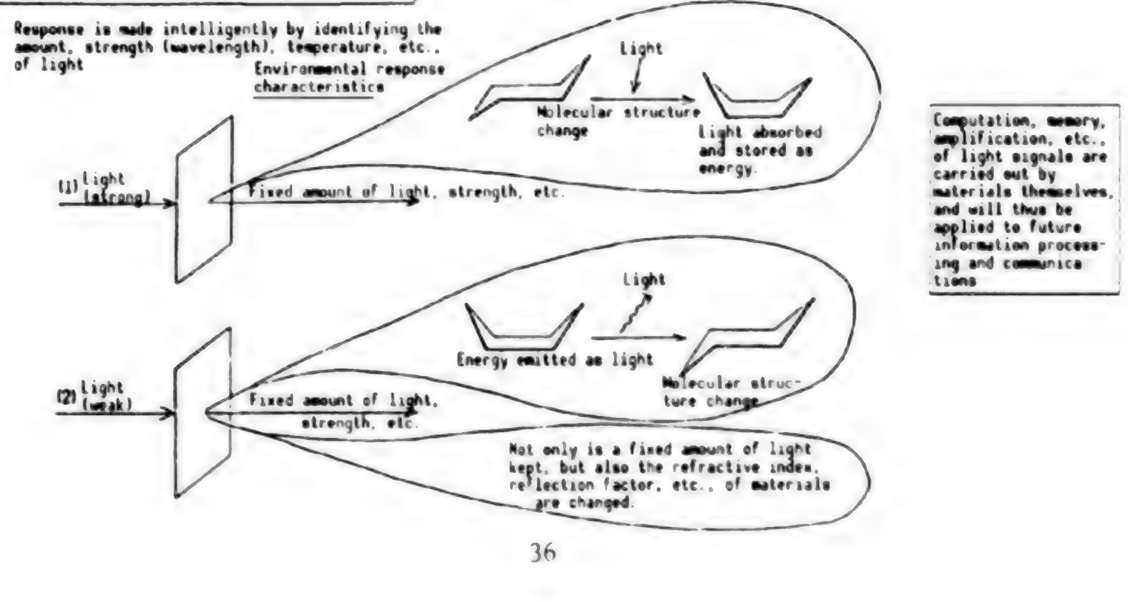
○ Advanced structural materials for aviation, space, and atomic energy use, which, in case of occurrence of deterioration, damage, etc., judge the condition of fulfillment of functions and the life of materials themselves, give a warning by such means as emitting sound and electrons, and restrict their development or effect self-repairing.



○ Medical materials such as veins and bones implanted inthe living body, which not only have the living-body affinity, but also grow or decompose according to the condition of growth or cure of the living body.



○ Optical materials for optical computer that can control refractive index, transmission factor, reflection factor, etc., by changing materials' optical characteristics according to changes in electric field, magnetic field, temperature, etc., automobile window glass and verifocal lens.



Superconductive Materials Research Multicore Project

Basic idea

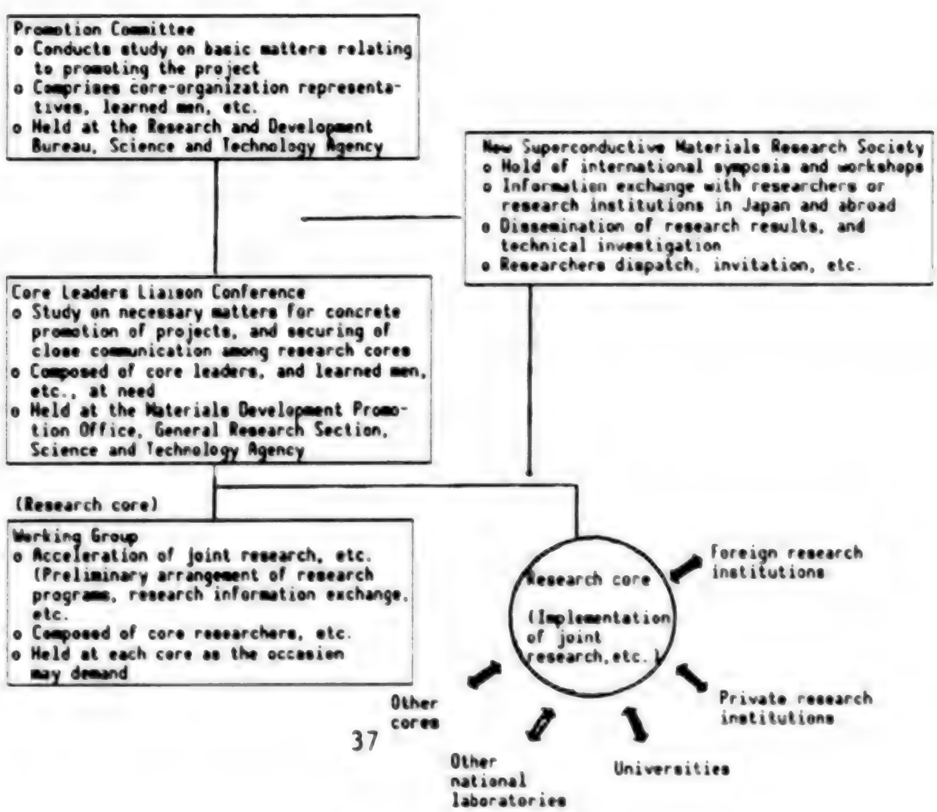
Stress laid on elementary and fundamental research

Figureless laboratory putting existing potential to practical use

Research system opened both at home and abroad

Research system mainly composed of researchers

Promotion Mechanism of Project



Research Cores

Target area	Research core	Core institution
Theory • Database	Theory Database	National Research Institute of Metals National Research Institute of Metals
Synthesis • Structure control	New substances probing Raw materials control Thin film making Single crystal making Fine processing Compound processing Space environment utilization	National Institute for Research of Inorganic Materials National Research Institute of Metals National Research Institute of Metals National Institute for Research of Inorganic Materials Institute of Physical and Chemical Research National Research Institute of Metals National Space Development Agency
Analysis • Evaluation	Superconductive performance evaluation Crystal structure analysis High-sensitivity composition analysis Radiation exposure/analysis Measurement/analysis support	National Research Institute of Metals National Institute for Research of Inorganic Materials Institute of Physical and Chemical Research Japan Atomic Energy Research Institute Materials Science and Technology Promotion Foundation
Technology development	Technology development	Research Development Corporation of Japan

(as of May 1991)

Diamond Synthesis Research

High-Pressure Synthesis

Year	National Institute for Research of Inorganic Materials	Other research institutions
1955		U.S. General Electric Co. invented the diamond grain synthesis method using metallic catalysis method
1969	8th Research Group (carbon) started diamond high-pressure synthesis research	
1970	Diamond grain high-pressure synthesis was made by the metallic catalysis method	GE successfully grew a large-sized diamond crystal by the metallic catalysis temperature-difference method
1975	Large-sized diamond crystal was successfully grown by the metallic catalysis temperature-difference method	GE established the sintered diamond synthesis method
1977	Superhigh Pressure Station started operating, and conducted high-pressure synthesis technology development research	
1986	High-purity sintered diamond was successfully synthesized	
1990	Diamond synthesis method using nonmetallic catalysis was invented	

Vapor-Phase Synthesis

Year	National Institute for Research of Inorganic Materials	Other research institutions
1955 - 1970		U.S., Soviet Union, etc.: Synthesis by vapor-phase method, ion-beam method tried
1969	7th Research Group began diamond research	
1974	Diamond Research Group began operation, began vapor-phase synthesis research	
1976		Soviet Institute of Physical and Chemical Research: Synthesis by vapor-phase method
1981	Vapor-phase synthesis by thermal filament method successful	
1982	Vapor-phase synthesis by micro-wave plasma CVD successful	

Technical Problems Relating to Diamond Vapor-Phase Synthesis

- Improvement in synthesis speed
- Area increasing, homogenizing
- Improvement in nucleus development density and bond strength
- Defect control
- Impurities control
- Improvement in epitaxy technology
- Diamond film evaluation technology

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DATE FILMED

27 Feb 1992